enrichment falter, the United States plans to be well prepared to assist. The AEC estimates the potential foreign exchange from uranium enrichment to be between $50 billion and $70 billion, and 9 of the 12 new plants that it recommends the United States have ready by the end of the century are intended to supply foreign customers.

While the official statements about the U.S. advantage in centrifuge technology may be sobering to the Europeans, the news could not have come at a better time for some American interests. The Administration and the JCAE have for several years been trying to entice U.S. industries into taking over the government's role in uranium enrichment—particularly the task of building new plants. Planning for large plants requires up to 8 years, so the time for decision is imminent. At the Oak Ridge briefing, Ray said that the two large industrial combines* that have undertaken serious plans to build enrichment plants will make final decisions by July 1974 whether to go ahead or not. The news that the technology available from the AEC is ten times better than what potential European competitors have is certainly not going to be discouraging.

Perhaps because they were overwhelmed by being admitted at last to the giant plant where the stuff of bombs has been extracted for the last 20 years, most of the reporters at Oak Ridge overlooked Ray's statement about the technology that will probably be the key to uranium enrichment for the next 20 years. Methods employing a laser may eventually make the centrifuge and diffusion processes both obsolete, however, as reported here last week (*Science*, 22 March 1974).

The Oak Ridge diffusion plant is a huge, dark factory, almost empty of people, where there is no visible movement. Only the loud humming of compressors indicates that uranium hexafluoride is being continually pumped through gigantic "stages," which look like room-sized beer kegs but are filled with porous barriers made of a secret material. In each stage, the fissionable isotope of uranium, ^{235}U, diffuses through the barrier slightly faster than the nonfissionable isotope, ^{238}U. After raw uranium passes through a "cascade" of 1200 stages, it becomes enriched from the natural concentration, which is 0.7 percent ^{235}U, to the concentration useful for a light-water reactor, about 4 percent. To produce the high concentration needed for weapons, about 97 percent, uranium from the Oak Ridge plant is shipped to Portsmouth, Ohio, where it is passed through several thousand more stages.

In a centrifuge process, uranium hexafluoride gas is fed into a spinning chamber through a hole in the rotor shaft. The complex forces at work in the rapidly spinning system accelerate the heavier component, ^{238}U, outward to the walls and downward, and a flow pattern is set up. As the fissionable isotope, ^{235}U, circulates through the pattern, it is preferentially passed into an upper chamber through small holes near the rotor shaft. Scoops rotating in the upper chamber collect the enriched ^{235}U component and also generate enough pressure to carry it to the next stage. The centrifuge which the AEC used as the beginning of its research effort in 1960 has a chamber 3 inches in diameter and revolves at about 90,000 revolutions per minute.

The reason a centrifuge plant can be made much smaller than a diffusion plant is that very few stages are needed. According to Urenco director, Donald G. Avery, speaking before the JCAE last October, "A centrifuge cascade requires in the region of 10 to 12 stages to achieve the ^{235}U concentration required for a plant to produce nuclear fuel." This does not mean that a dozen centrifuges can produce fuel, because different numbers of centrifuges must be used in successive stages to achieve a graded flow capacity. But Avery said that a satisfactory cascade can be put together with as few as 100 centrifuges. The optimum number would certainly be larger, but even so a gas centrifuge production plant would certainly comprise many independent cascades. In contrast, a diffusion plant has only one cascade with the very large stages to achieve the maximum economy of scale. The flexibility of a centrifuge plant derives from the fact that it can be built up cascade by cascade, whereas a diffusion plant cannot produce enriched uranium until all the components of its single cascade are completed. Avery said that the Urenco partners have produced more than 8000 centrifuges.

The announcement that the AEC holds a substantial advantage in gas centrifuge technology is certain to have a chilling effect on the potential customers of Urenco, and could slow the trend for European utilities to buy their nuclear fuel at home. The AEC claim of superior technology may simply be a statement of justifiable pride in successful research. But it could also be a bargaining chip designed to keep European customers looking to America for uranium enrichment.

—WILLIAM D. METZ

* General Electric Company together with Exxon Nuclear Company, and Uranium Enrichment Associates, whose parent companies are Bechtel Corporation, Union Carbide, and Westinghouse.

Medical Education: Institute Puts a Price on Doctors' Heads

It costs $12,650 a year to educate a doctor. If you subtract from that sum the costs of research and patient care that can be considered essential to medical education, the cost comes down to $9700 a year, on the average. This is the price the Institute of Medicine of the National Academy of Sciences puts on doctors' heads.

The Association of American Medical Colleges (AAMC) puts it somewhat higher. According to the AAMC, the cost of medical education ranges between $16,000 and $26,000 a year, depending on where one goes to school.

These price tags are the products of studies that both organizations have been conducting on the cost of education. The institute's figures were released last month in its report *Costs of Education in the Health Professions*, which includes data on what it costs to educate persons in seven health professions in addition to medicine (see table).* The 18-month, $2.3-mil-

* This article deals primarily with the study's findings regarding the cost of medical education.

lion cost study was conducted in response to a congressional request written into the Comprehensive Health Manpower Act of 1971, which introduced "capitation" grants as a method for federal support of schools educating doctors and other health professionals. The act, and the controversial capitation system, by which schools get payments on the basis of the number of students enrolled, expires in June. Congressional hearings on whether to continue this or any other method of federal financing of medical education are expected to be scheduled soon.

The AAMC's study, begun in 1970, was released in preliminary form last October with a notation that said, "The first part of the committee's work is made available prior to the completion of the full study in accordance with the Association's objective to provide pertinent data on all phases of medical education as quickly as the information is developed." As yet, it provides no figures that can be compared specifically with the institute's, except those pertaining to the range of costs.

Congress asked for the institute study to help it get itself out of the bind it got in when it passed the manpower act. Under the law, the government would make direct "capitation" payments to schools to help finance medical education. But no one had any clear idea of what it cost to educate a doctor, or a dentist, or a nurse, and the capitation system logically requires such information. The institute, fully aware that it was getting into a perilous area, agreed to try to determine educational costs.

However, since it began its study in June 1972, the very idea of capitation has lost its early appeal. To some extent, capitation followed from the premise that the country is facing a doctor shortage and that medical schools should be encouraged to expand their enrollments to provide more new doctors. The idea was that if the federal government paid each school a given sum for every student it enrolled, schools could be expected to increase their enrollment.

If everyone subscribed to that premise 3 years ago, it is apparent that there is no consensus today about whether we have too few doctors or too many.

The Nixon Administration is clearly of the opinion that there is no doctor shortage. Charles C. Edwards, assistant secretary for health in the Department of Health, Education, and Welfare, thinks we may even be in danger of producing too many. "I think that clearly we have moved beyond the point at which concerns about a shortage of M.D.'s were genuine, if somewhat exaggerated. In my judgment, even more significant is the possibility that we may well be facing a doctor surplus in this country," he said last fall in an address before the AAMC, that hardly won the hearts and minds of his audience.

Average and range of annual education grants per student by profession, 1972–1973. (Figures are rounded to the nearest $50.)

Profession	Average ($)	Range ($)
Medicine	12,650	6,900–18,650
Osteopathy	8,950	6,900–12,350
Dentistry	9,050	6,150–16,000
Optometry	4,250	3,750– 4,750
Pharmacy	3,550	1,600– 5,750
Podiatry	5,750	4,400– 6,700
Veterinary medicine	7,500	6,050–10,500
Nursing		
Baccalaureate	2,500	1,200– 4,500
Associate	1,650	1,050– 2,150
Diploma	3,300	1,850– 4,850

Officials of HEW will almost certainly oppose continuation of the capitation system when they testify at the congressional hearings, and there is no evidence that members of Congress are wedded to capitation as a mechanism for supporting medical education. Therefore, it is possible that it will be phased out.

An anticipated argument about educational subsidy between the Administration and Congress will pick up from there. The Administration is questioning the need to support medical education at all. The lines of applicants at medical schools, HEW officials point out, are long. The ultimate incomes of doctors are high. Why should the government subsidize their education? They reason that there will be enough doctors without federal money, and those who cannot afford the tuition can take out loans they should be well able to repay.

Congress is not likely to buy this reasoning. The institute does not, and in its report explicitly calls medical schools a national resource that requires federal support. HEW officials do not disagree; nor do they find this a persuasive argument on behalf of continued federal support.

The institute skirted the doctor shortage controversy, saying simply that the data are inconclusive. However, it does not recommend that medical school enrollments be greatly increased, suggesting instead that efforts be made to maintain the status quo. As far as capitation funding is concerned, it urges that money be allocated on the basis of graduates, rather than enrollments. As one cost study person pointed out, "The nation needs doctors, not students."

The institute study focused squarely on the capitation system, as Congress asked it to, and now that capitation appears to be on its way out, there are questions about the usefulness of the study. Some persons at HEW have criticized the study for failing to address the question of *whether* capitation is a sound form of financial support but think the figures it has come up with will, nonetheless, be useful.

Economist Ruth Hanft directed the study, which had a full-time staff of 35. Julius Richmond, an M.D. who heads the Judge Baker Guidance Center in Boston, chaired the nine-member steering committee of doctors, other health professionals, and medical economists. Unlike many institutional studies in which experts convene occasionally to review available literature and their own thoughts in order to reach a conclusion, the institute staff developed its own methodology and its own data to determine educational costs.

One item that had to be decided was whether the goal should be to arrive at a single dollars and cents figure or a range of costs. The latter appealed to those who argued that it really is impossible to set a specific figure that applies equally to all medical schools. The idea of reporting a single figure seemed right to those who said that if the results were to be of any use to Congress, which would have to decide on a capitation figure that would be the same for all schools, a single, graspable sum was necessary (*Science*, 2 June 1972). The single-sum view prevailed, hence the $12,650 price tag on doctors. Not that the institute does not recognize a range of costs—it does. Its range for medical schools, for instance, is $6,900 to $18,650. But unless Congress is willing to pay more to the more expensive schools, which it is not, the range is not of central importance in this situation. (The average cost of private schools is 24 percent higher than the average cost of public institutions.)

The institute approached the problem of determining educational costs by starting with a fairly simple premise—time is money. Faculty members at 14 medical schools, selected because they were judged to be representative of the 93 fully operational medical schools in the United States, were asked to keep detailed logs of their activities for 1 week, recording the amount of time they spent teaching, the amount doing research, and the amount taking care of patients. It then became necessary to decide how much research and how much patient care can be called *essential* to medical education and how much must stand on its own. Time logs could not provide answers to that question, which required as much judgment as hard data. So, the institute convened a "constructed cost seminar" of medical educators, administrators, and other knowledgeable persons to arrive at the answer.

Meeting at Airlie House, a retreat in the Virginia countryside, seminar members were asked to "construct" a medical school on paper. They devised a curriculum for the imaginary school of about 200 students and provided it with a faculty, research laboratories, hospital beds for patients, an administration, and other necessities.

Their plan was to create a school that would be good for students and faculty alike. Their consensus was that, in the basic sciences, faculty members should spend two-thirds as much time in research as in teaching. A man who spends 30 hours a week in the classroom should spend 20 hours in his laboratory. In the clinical sciences, they judged necessary proportions of time to be somewhat different. To keep abreast of his field and conduct research while teaching, the clinical investigator should spend about one-third as much of his time in research as he does in instructing students.

Armed with this information, the cost study staff determined the average annual "net education" cost of putting a student through medical school, the $9700 price tag. They said that medical institutions receive revenues to support research and to pay for patient care and that some of these revenues should be subtracted from the amount that can be billed to education alone. What they call "offsetting research revenues" come to an average of $2100. "Offsetting patient care revenues" amount to $1300. Therefore, the institution must come up with $9700 a year from other sources—tuition, fees, federal and state subsidies, and so forth—in order to meet the cost of educating a doctor. The institute recommends that the federal government pick up somewhere between 25 and 40 percent of this $9700 bill, which is approximately what it is supposed to be doing now through capitation grants.

Whatever happens to federal financing of education for health professionals the institute pegs as the primary problem the absolute lack of any coordination in federal policies in this area. "In health professional education, the federal shifts of emphasis among research, education, and patient care have usually been made without sufficient consideration of the fact that all three programs contribute to the educational environment of most health students. The support of that environment requires a balance among its programs and a stability of financing that have not been manifest in federal policy thus far." Therefore, the study group recommends that "whatever financing method eventually emerges for health professional education, it should be accompanied by a mechanism for review and coordination in the legislative and executive branches of the federal government."

—BARBARA J. CULLITON

Journals: Photocopying Is Not the Only Problem

The effort to revise the copyright law has kept Congress in one of its longest running quandaries. At one point during a day's hearing on library photocopying last summer, Senator John L. McClellan (D–Ark.) commented testily, "Well, I am not going to get into that business. I am just puzzled and perplexed and I guess confused like most everybody in trying to resolve this problem. I think I have a full measure of sympathy for all interests; I mean, I would like to see the publisher and author and so forth compensated, and at the same time, I don't know how you could base it on this 5 percent rate paid by whoever gets a copy, and make this thing work. I don't know how it is going to be practical."

McClellan's comments were prompted specifically by a publisher's proposal to levy a licensing fee on library photocopying, but perplexity has been the dominant congressional reaction to the copyright problem. For more than a decade, Congress has sought to carry out a major revision of the copyright law to deal with the changes in technology, in the habits of users, and in the economics of publishing since the present law was enacted in 1909.

It appears that Congress may at last be about to emerge from the maze. Sources close to the Senate Judiciary Committee's subcommittee on patents, trademarks, and copyrights, of which McClellan is chairman, expect that a copyright revision bill will be reported out in the reasonably near future.

For scientists and engineers the matter of photocopying journal articles has been the liveliest issue in the debate over revision. As it stands at the moment, the draft bill is said to give legislative support to current photocopying practices.

Attention has been focused on the photocopying issue by a suit brought by the Baltimore publisher of scientific and medical journals, Williams & Wilkins, charging the National Library of Medicine and the library of the National Institutes of Health with copyright infringement via photocopying. The most recent round of court action favored the defendants, permitting them to continue photocopying. The court decision, in effect, however, put pressure on Congress to resolve the issue legislatively.

Reduced to its essentials, the dispute over photocopying casts scientific publishers and research libraries as the major antagonists. The libraries want the right to continue to provide a single photocopy for a reader who requests it.